Streamflow and Second-Home Development in Northern Arizona
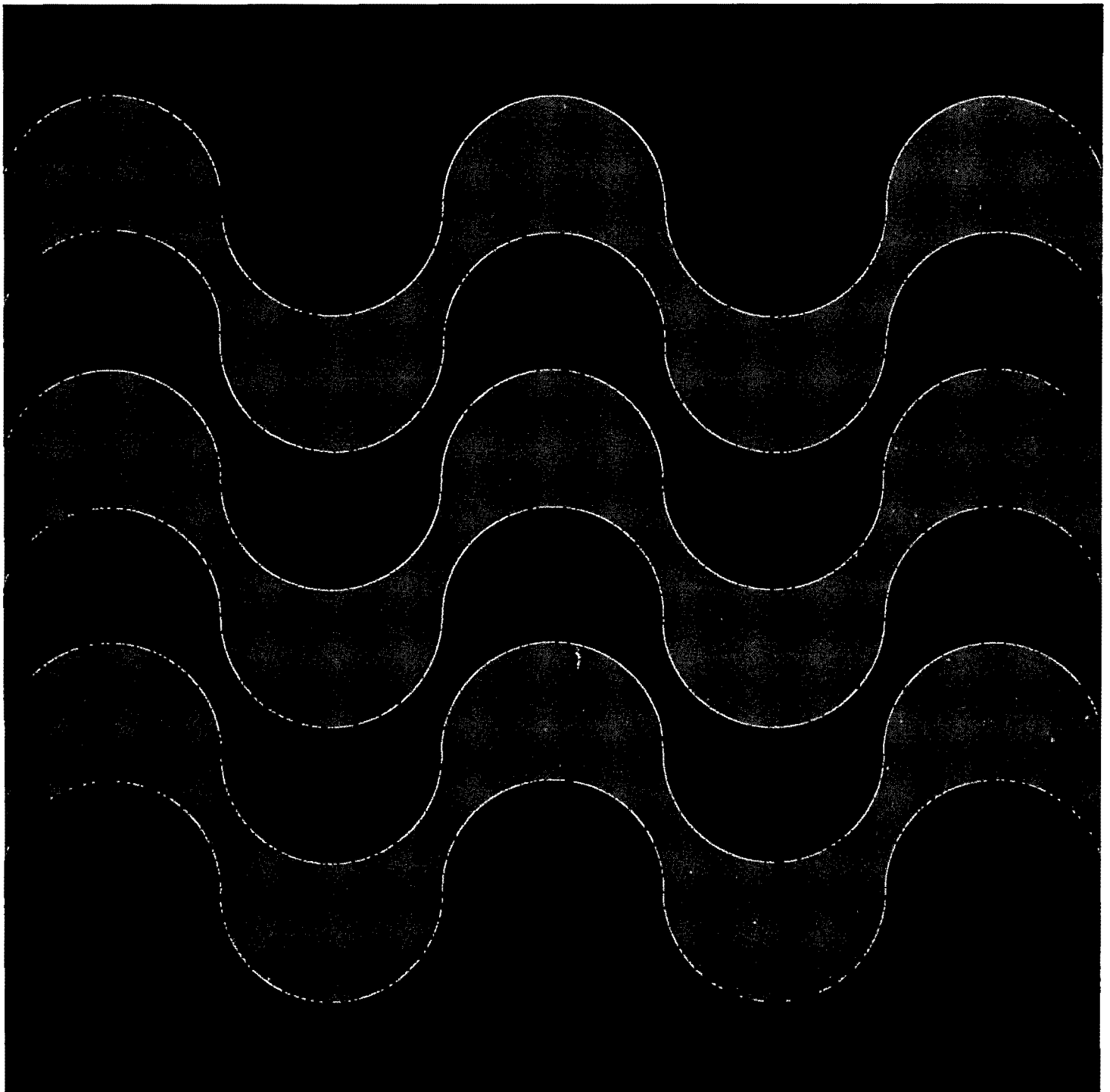
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STREAMFLOW AND SECOND-HOME DEVELOPMENT
IN NORTHERN ARZIONA

by

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PREFACE

This study was initiated to examine the relationship between second-home development and the patterns of surface runoff in affected watersheds. The project was sponsored by the Eisenhower Consortium for Western Environmental Forestry Research as one of a series of studies relating to water quality/quantity questions within the context of forest environments. We are grateful for the Eisenhower Consortium sponsorship and for the assistance received from U.S. Forest Service personnel of the Apache-Sitgreaves National Forests and of the Rocky Mountain Forest and Range Experiment Station. In particular, we would like to thank Gordon D. Lewis, Program Manager, for his valuable assistance in the completion of this study.

A number of people aided us during the course of this study. Shelby Gerking provided us with the seasonal electric hookup data series utilized in the empirical analysis, and personnel from the Navopache Electric Cooperative, from which Gerking obtained these data, also assisted us to correctly interpret these data for our use. Many members of the Bureau of Business and Economic Research provided invaluable help at various stages in the project. Robert Mitchell assisted with several aspects -- the review of existing literature, the statistical analysis, and the computer production of the graphs presented in the study. Editorial review was

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CHAPTER I

INTRODUCTION

Water is often called Arizona's most precious resource: It plays a key role in products that are vital to the state's economy and has profound effects upon the lifestyle and consumption standards of the state's residents. Moreover, water receives frequent attention because of controversy over surface water rights, and because irregular acts of God such as storms, floods, or droughts affect both production and resident lifestyles. In addition, the importance of water is exemplified by the growing demand placed on groundwater supplies by an expanding Arizona economy.

Management of water resources is a recognized need and goal within the state, and ongoing work has been directly related to this purpose. One area of recent investigation has concerned the relationship between water and rural residential development. Specifically, questions have been raised regarding forest land use for broad-based recreational purposes and the impact of such activities on stream discharge and water availability.

With specific reference to Arizona, data related to second-home activity have begun to be developed. Recent studies have added much new knowledge on second-home development within the state, e.g., numbers, growth trends, characteristics of owners, and other information.

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The major purpose of this study was to bring together water data and information on second-home development to discover whether any discernible relationship could be identified between second-home development and water flows. The research specifically focused on surface water conditions, as measured by stream discharge readings, and was restricted to areas where both second-home data and stream discharge data were available.

The methodology for this study was determined by both time and financial constraints. Limited allocations of both resources precluded a long-term field-data collection effort for project analysis. Hence, time series data from existing secondary sources were used for the analyses.

Prior investigations recognized that second-home development would predictably affect runoff volumes and flow measures where the streams were adjacent to the second-home locations. Construction of dwellings, roads, public facilities, and related structures would heighten stream discharge during rains because of the increased immediate water runoff and would lessen the measured flows in nonrain periods because of reduced groundwater absorption and ground seepage.

The seriousness of this relationship -- or, the measurability of the relationship through the use of secondary data -- had not been tested in the context of second-home and resort-town development. Thus, without preconceived expectations, the research

was directed toward examining (testing) the relationships of watershed changes associated with such development and the resultant impacts on streamflow.

This report is grouped into the following chapters: Chapter II presents a brief review of some relevant studies; Chapter III specifically examines the trends in second homes in the defined study area; Chapter IV presents the stream discharge trends for the study area; Chapter V assesses the empirical relationships and the implications of these findings; and Chapter VI provides an overview of the study's findings and recommendations for further research.

CHAPTER II

LITERATURE REVIEW

This study involves the interrelationships between two research

areas: (1) analyses of the factors affecting streamflow patterns

and (2) studies related to second-home development and its resulting

social, economic, and environmental impacts.

STREAM DISCHARGE STUDIES

A wide variety of research has investigated the determinants

of streamflow. Theoretical analyses have examined and specified

the fundamental relationships between watershed characteristics

and the flow characteristics of the streams draining that water-

shed. The following equation identifies the basic water relation-

ships within environment:

Precipitation = Runoff + Evapotranspiration + change in storage.[1]

Assuming that over a period of time precipitation and

storage remain relatively constant, runoff and evapotranspiration

will vary inversely to one another. Evapotranspiration is heavily

dependent on the vegetation and the land surface, and any change

to either of these variables will cause a change in the volume of

runoff.

Crawford has succinctly summarized the basic watershed

reaction relations as follows:

Watershed reaction can be considered in two classifications, runoff volume and runoff timing. Runoff volume is determined at the land surface. Long-term runoff timing is controlled by the channel system. Thus land surface processes (infiltration, depression storage, and interception) need to be modified if changes in runoff volumes or long-term timing are required. Channel system processes and characteristics (channel's cross sections, roughness, or slope) are usually considered if short-term timing is to be modified.

The processes associated with the land surface are (a) interception; (b) depression storage; (c) infiltration and soil moisture storage; (d) evaporation; (e) overland flows; (f) interflow and groundwater flow. The first four items listed -- interception, depression storage, infiltration and soil moisture storage, and evaporation -- determine runoff volume. The time distribution of this runoff on a weekly or monthly time scale is determined by the relative importance of direct runoff (overland flow) and of delayed flow (interflow or groundwater). Depression storage and infiltration are most closely associated with runoff volumes during a storm. Evaporation processes modify soil moisture between storms and therefore change infiltration during storms.[2]

Roberts graphically demonstrated these watershed relations in his study of the Jackson Creek watershed on the rural-urban fringe of Bloomington, Indiana (Figure I). A larger peak discharge occurs earlier and total runoff increases with the increase in impervious urban land areas.[3]

Hammer advanced these relationships in his comprehensive study of stream channels and streamflow in Maryland and Pennsylvania. The earlier larger peak discharge was determined to be attributable to two causes: (1) the decrease in lag time (time from the

FIGURE I

GEOHYDROLOGIC CHANGES THAT RESULT FROM THE URBANIZATION OF A RURAL WATERSHED

RURAL

URBAN

FLOOD
HYDROGRAPHS

Discharge

Urban

Rural

Time

1 Natural drainage net
2 Water-table
3 Septic tank
4 Water well
5 Storm sewer
6 Pollution of groundwater by septic tank
7 Reduction of the length of natural streams
8 Roads form an artifical drainage net
9 Increase in impermeability
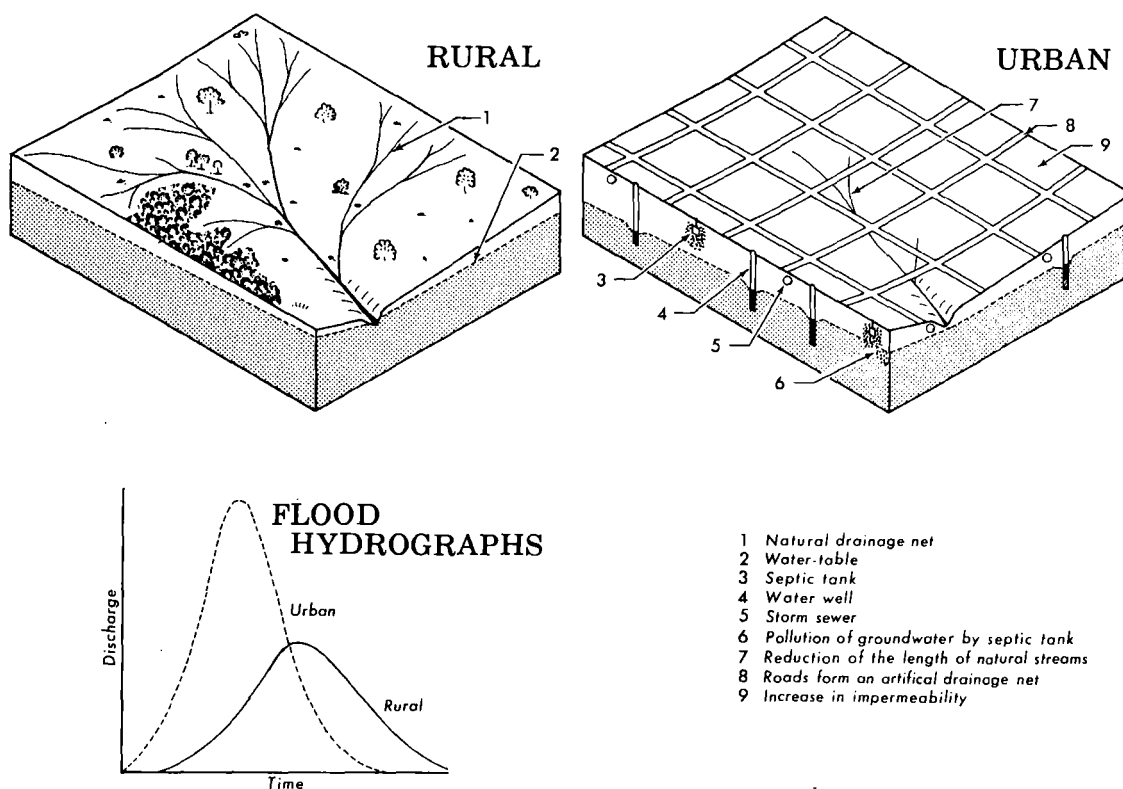
Source: Michael C. Roberts, "Watersheds in the Rural-Urban Fringe," in Watersheds in Transition, (Urbana, Illinois: American Water Resources Association, 1972).

beginning of the storm to peak discharge), and (2) an increase due

to change in runoff volume.[4]   Another conclusion reached by Hammer

concerned the effects of urbanization at different times of the

year: "The results indicated that urbanization has a much greater

influence on 48-hour discharge (runoff from a given storm) during

June-November than December-May. The difference in the estimated

exponents--which was statistically significant -- can probably be

attributed to factors such as freezing of the soil and reduction

of vegetative cover in winter and wet antecedent conditions in the

spring, which cause a high proportion of rainfall to run off with

or without urbanization."[5]

Sawyer quantified the difference in total runoff between

urban and rural watersheds in his study of Nassau County, New York.

Two watersheds were compared over a period of twenty-three years.

For the first twelve years of the study, population grew at the

same rate in both areas. From 1950 to 1955, however, population

increased by 130 percent in the area (about ten square miles)

drained by East Meadow Brook while population increased only 30

percent in the Mill Neck Creek basin (about thirty-one square

miles). Precipitation was measured at one nearby station. Table 1

summarizes the findings of the study, with direct and total runoff

in the urbanized watershed increasing at 123.1 percent and 15.8

percent respectively as compared to 6.1 and 7.2 percent for the

less densely populated watershed. Sawyer concluded, "The changes

TABLE 1

AVERAGE ANNUAL PRECIPITATION AT MINEOLA AND
RUNOFF OF MILL NECK CREEK AND EAST MEADOW BROOK
(Inches)

	Precipitation	Runoff of Mill Neck Creek			Runoff of East Meadow Brook		
		Total	Direct	Base	Total	Direct	Base
14 years (1938-51)	43.31	11.17	0.99	19.18	7.29	0.65	6.64
9 years (1952-60)	47.40	11.97	1.05	10.92	8.44	1.45	6.99
Increase	4.09	.80	.06	.74	1.15	.80	.35
Increase, in percent	9.4	7.2	6.1	7.3	15.8	123.1	5.3

Source: R. M. Sawyer, "Effects of Urbanization on Storm Discharge and Groundwater Recharge in Nassau County, New York," Geological Survey Research, 1963, p. 187.

at East Meadow Brook are probably due to the change in land surface from pervious to impervious material as well as to the increase in precipitation."[6]

Two subsets of such empirical analyses of watershed changes upon streamflow are of particular interest to this project. The first includes investigations of the effects of changes in vegetation upon the runoff of existing watersheds.[7] In general, results demonstrate that forest removal both increases the volume of runoff and significantly modifies the time pattern of that runoff. The second body of existing literature related to the impact of second-home development is that which investigates the impact of urban growth upon streamflow.[8] The available evidence indicates that the land use changes associated with urban development have significant impacts upon hydrologic relations. Waananen has summarized these effects in the following list:[9]

1. Increase in total yield from stormflow and in annual discharge

2. Decrease in base flow of those streams that remain under generally natural conditions

3. Modification of low flow of streams influenced by the importation of water, the use of which results in discharge of wastewater. This includes the increase of low flow in streams that receive septic tank drainage, or effluents from sewage treatment plants, or from industrial plants.

4. Decrease in recharge to the underlying groundwater basins

5. Increase in precipitation in urban areas and corresponding increase in yield

The research methodology generally employed in these empirical studies has been subject to criticism that many of the relevant variables are difficult to control or measure, so that the results obtained are of significance only for the particular study location. R. C. Ward wrote in reference to rainfall-runoff studies, "The most easily instrumented and least valuable watershed experiments...shed little light on the hydrological complexity of the study area.... The underlying weakness of most all rainfall-runoff studies is that the data represent only a part of the inputs and outputs of a complex watershed system."[10]

SECOND-HOME STUDIES

The forested areas of northern and eastern Arizona provide a major portion of the total state surface runoff, which is vital to the state's agricultural sector and to its metropolitan areas. Coinciding with the rapid growth of Arizona's population in the post-World War II period has been an equally dramatic trend of second-home development in the rural areas of the state. Much of this development has occurred in these same northern and eastern counties to provide summer homes in the cooler mountain areas for the residents of the populous Phoenix and Tucson metropolitan areas.

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No comprehensive study of second-home development in Arizona

has yet been undertaken, but some information on the extent and

characteristics of the development can be compiled from a variety

of sources. Thompson and Lewis conducted a U.S. Forest Service

study of residential development on private land in the Mogollon

Rim areas of the state (including prime second-home areas in

Coconino, Gila and Navajo Counties). They estimated, on the basis

of property tax records, that there were 150 subdivisions containing

16,000 lots within their study area in 1972. Their analysis also

revealed that dwelling units had been constructed on only 3,300 of

those lots up to that year -- almost 90 percent frame structures

with mobile homes on the remainder.[11] A 1975 Arizona Office of

Economic Planning and Development inventory of remote subdivisions

included information on the subdivision development in forested

areas of the northern counties. The data related only to the

numbers of subdivisions, lots, and acreage, and did not provide

information on the actual numbers of second homes. Nevertheless,

the inventory identified the existence in 1975 of almost 49,000

lots in such subdivisions, comprising over 67,000 acres in Apache,

Coconino, Gila, and Navajo Counties.[12]

Under two previous U.S. Forest Service grants through the

Eisenhower Consortium, the Bureau of Business and Economic Research

examined second-home developments in northern Arizona. In 1977,

Bond and Dunikoski examined the impact of such developments on

water availability in Arizona, and inventoried the number of second

homes within the major second-home areas of Coconino, Gila, Navajo,

and Yavapai Counties.[13] Using data from U.S. Forest Service maps for

1967 and property tax records for 1975, Bond and Dunikoski esti-

mated there were 5,500 second homes in 1967 and 10,500 within the

study area in 1975; based upon these data, together with analysis

of additional information, they also projected the number of

second homes within their study area would grow to over 21,000 by

1985. In another study published in 1977, Hogan surveyed a sample

of owners of homes in five prime second-home areas in northern

Arizona. The information collected by this survey provides a

profile of the homes located in these second-home communities and

information on the households who owned the homes, although the

survey did not specify data on the total number of second homes in

the areas.[14]

A third project, also funded by the Eisenhower Consortium,

has specifically examined the trend in second-home development in

northeastern Arizona. To develop a short-term forecasting model for

second-home construction, Gerking, Holmes, and VanBrackle studied

second-home development in Navajo and Apache Counties during the

1958-1977 period.[15] On the basis of field work, they concluded

that: (1) the number of second homes in the area had grown

dramatically, particularly in the last ten years; (2) most of this

development has occurred in the Show Low-Pinetop-Lakeside area;

(3) the prospects for future development, at least over the near

term, appear bright; and (4) data on second homes in Navajo and

Apache Counties were difficult to obtain but an acceptable proxy

measure was available from electric utility records kept by the

Navopache Electric Cooperative, Inc.[16]

The growing magnitude of rural residential development has

led to increasing research concerning the possible economic,

social, and environmental impacts upon the areas and the nearby

communities where such development is occurring.[17] Looking

specifically at water issues with respect to second-home develop-

ment, most of the analyses have discussed second-home development

in terms of its impacts upon the local demand for water, upon the

erosion of nearby lands, and upon water quality in affected streams.

Relating directly to the areas in northern Arizona, Bond and

Dunikoski examined the magnitude of water depletions associated

with second-home use and reached the conclusion that future develop-

ment would have only minor impact upon water availability in the

affected hydrologic regions.[18] Bricklen and Utter examined the

water quality issue in a study of three lakes and three streams in

the White Mountains of northeastern Arizona. Although vacation

homes, campgrounds, and day-use sites were located within the

watersheds of all of the recreation waters in the areas, no major

pollution problems were identified in the lakes and streams studied.

The authors concluded that the potential for problems does exist

unless research or land managers' current endeavors are continued
and expanded.[19] Little published research is available, however,
which investigates the effects of second-home development upon
stream discharge.

OVERVIEW

A search of existing information has identified a large body
of existing information related to the subject considered by this
project, and these findings provide a valuable foundation for the
study. While substantial research has previously examined the
impact of watershed changes in forested areas, most of the research
has concentrated on forest management or timbering effects, rather
than second-home development. Similarly, most existing analyses
of the impact of the land-use changes upon the pattern of stream-
flow have examined the phenomenon in an urban setting and in
nonforested areas.

NOTES

[1]N. H. Crawford, "Analysis of Watershed Changes," in Effects of Watershed Changes on Streamflow, ed. W. L. Moore and C. W. Morgan (Austin, Texas: University of Texas Press, 1969).

[2]Ibid, pp. 27-28.

[3]M. C. Roberts, "Watersheds in the Rural-Urban Fringe," in Watersheds in Transition, (Urbana, Illinois: American Water Resources Association, 1972) p. 393.

[4]T. R. Hammer, "Effects of Urbanization on Stream Channels and Streamflow," (Springfield, Virginia: National Technical Information Service, 1973). PB-229-836, p. 157.

[5]Ibid, p. 157.

[6]R. M. Sawyer, "Effects of Urbanization on Storm Discharge and Groundwater Recharge in Nassau County, New York," Geological Survey Research, 1963, p. 187.

[7]See, for example, E. F. Aldon, "Groundcover Changes in Relation to Runoff and Erosion in West Central New Mexico," U.S. Forest Service Research Note, RM 34. 1964; J. D. Hewlett and A. R. Hibbert, "Increases in Water Yield After Several Types of Forest Cutting," I.A.S.H. Quarterly Bulletin, (September 1961), pp. 5-17; A. R. Hibbert, "Forest Treatment Effects on Water Yield," in Forest Hydrology, ed. W. E. Sooper and H. W. Lull, Pergamon Press, 1966, pp. 527-543; W. L. Moore and C. W. Morgan (eds.), Effects of Watershed Changes on Streamflow, (Austin, Texas: University of Texas Press, 1969); H. G. Reynolds, "Watershed Management Research in Arizona and New Mexico," Journal of Forestry, 58, 1960, pp. 275-278.

[8]See, for example, E. E. Harris and S. E. Rantz, "Effect of Urban Growth on Streamflow Regimen of Permanente Creek, Santa Barbara County, California," U.S.G.S. Water Supply Paper 1591 B, 1964; J. Savini and J. C. Hammerer, "Urban Growth and the Water Regimen," U.S.G.S. Water Supply Paper 1591 A, 1961; and A. O. Waananen, "Urban Effects on Water Yield," in Effects of Watershed Changes on Streamflow, ed. Moore and Morgan.

[9]A. O. Waananen, "Urban Effects on Water Yield," in Effects of Watershed Changes on Streamflow, ed. Moore and Morgan, p. 181.

[10]R. C. Ward, Small Watershed Experiments, (Hull, England: University of Hull, 1971) pp. 26-30.

[11] J. C. Thompson and G. D. Lewis, "Rural Residential Development on Private Land in the Mogollon Rim Area of Arizona," Mogollon Rim Comprehensive Land Use Plan, (U.S. Forest Service: Albuquerque, New Mexico, 1973).

[12] Arizona Office of Economic Planning and Development, Arizona's Remote Subdivisions: An Inventory, Phoenix, Arizona, 1975.

[13] M. E. Bond and R. H. Dunikoski, The Impact of Second-Home Development on Water Availability in North Central Arizona, Eisenhower Consortium Institutional Series, Report No. 1, Bureau of Business and Economic Research, College of Business Administration, Arizona State University, Tempe, Arizona, 1977.

[14] T. D. Hogan, Second-Home Ownership in Northern Arizona: A Profile and Implications for the Future, Eisenhower Consortium Institutional Series, Report No. 2, Bureau of Business and Economic Research, College of Business Administration, Arizona State University, Tempe, Arizona, 1977.

[15] S. D. Gerking, C. J. Holmes, and M. VanBrackle, "A Short-Term Forecasting Model for Second Homes in Northeastern Arizona," Final Report in Grant 16-699-GR, U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado, 1979.

[16] Ibid, pp. 18-20.

[17] See, for example, I. U. Fine and R. E. Tuttle, Private Seasonal Housing in Wisconsin, (Madison, Wisconsin: State of Wisconsin, 1966); R. N. Brown, The Economic Impact of Second-Home Communities: A Case Study of Lake Latonka, Pennsylvania, ERS-652, (Washington, D.C.: U.S. Department of Agriculture, 1970); M. E. Johnson, Utah's Subdivision Problem, Bureau of Community Development, (Salt Lake, Utah: University of Utah, 1973); Task Force Report: Impacts of Rural Residential Development, Center for Interdisciplinary Studies, (Bozeman, Montana: Montana State University, 1974); and a number of papers, including those of Clark Welch, Chase and Hoff, Montague, Lewis, Parker and Kneese, Bricklen and Utter, Segal, Berman, Bedwell, and Fox in Man, Leisure and Wildlands: A Complex Interaction, Proceedings of the First Eisenhower Consortium Research Symposium, Vail, Colorado, September, 1975.

[18] Bond and Dunikoski, pp. 71-74.

[19] S. K. Bricklen and J. G. Utter, "Impact of Recreation Use on Water Quality in the White Mountains of Arizona," Final Report on Cooperative Agreement 16-340-CA, U.S. Forest Service, Rocky Mountain Forest and Range Experiement Station, Ft. Collins, Colorado, 1975.

CHAPTER III

SECOND-HOME TRENDS IN THE STUDY AREA

The northern sections of Arizona contain a major portion of the state's higher elevations and consequently account for a significant portion of the land area where surface water runoff originates. This is also a major area of the state where second-home activity has been expanding.

Previous research, cited in the preceeding chapter, has provided substantial evidence of the rapid pace of second-home development in northern Arizona during recent years. For example, Bond and Dunikoski examined estimated second-home trends over nearly a decade,[1] and the northern tier of communities all showed significant growth. Hogan looked at many characteristics of second-home owners and found that substantial second-home development is expected based on projected population increases in Arizona and Maricopa County.[2]

DATA REQUIREMENTS

The major objective of this research is to determine whether a statistical relationship can be determined between second-home development and stream discharge. Such an analysis requires a time-series approach for the analysis. Cross-sectional analyses would fail to account properly for the changes in either variable set.

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Much of the work on second homes has been of a cross-sectional nature. Some time series estimates were developed in the Bond-Dunikoski report; however, these were used principally as trend indicators rather than as any true reflection of time series estimators.

In another second-home study, Shelby Gerking looked at demand patterns for second homes in northern Arizona.[3] Gerking used data from the Navopache Rural Electric Cooperative, a utility serving parts of Navajo and Apache Counties, to develop estimates on second homes. For this study, the Navopache Rural Electric Cooperative data are also used.

These utility records were justified for use in this study for the following reasons:

1. The utility serves one of the principal northern Arizona areas where second-home growth has been active. For example, in the Bond-Dunikoski report, it was estimated that in 1975, in southern Navajo County alone there were nearly 2,600 second homes. As can be seen from Figure II, the service area of the utility is in this growth area.

2. The utility maintained monthly records on "seasonal connections." At the time of this study the utility maintained a very minimal charge for seasonal off/on power connection charges, and most seasonal second-home owners could minimize their annual utility outlay by a seasonal connect/disconnect charge rather than pay a monthly minimum charge for periods of nonuse. Persons at

FIGURE II
SERVICE AREA OF THE NAVOPACHE RURAL ELECTRIC COOPERATIVE

Navopache Electric Coop

Source: Navopache Rural Electric Cooperative

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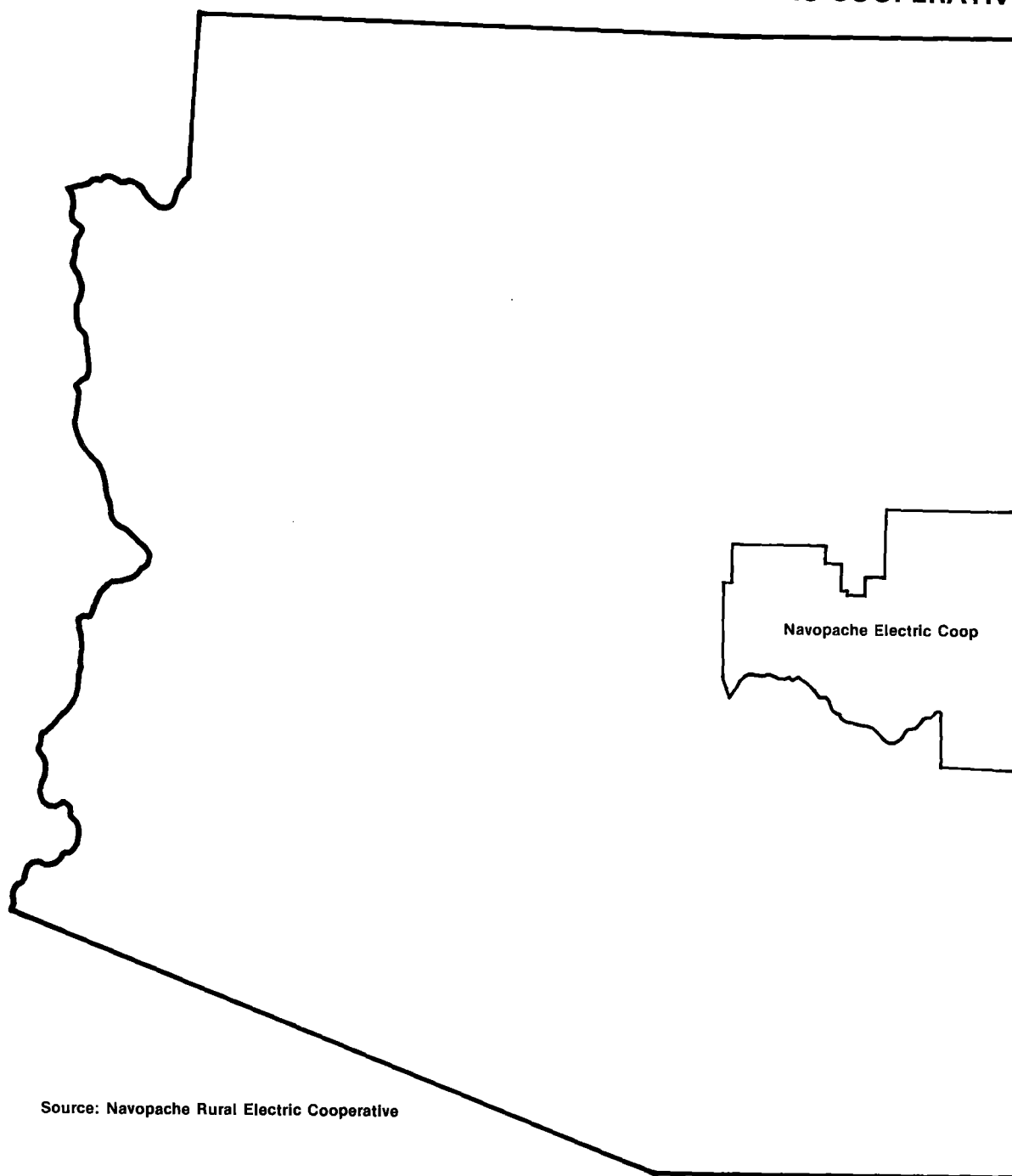
the utility agreed that most of the seasonal connections were for

summer cabins; thus, it was determined that these data would

provide one means to acquire a time series on second-home activity

that would not otherwise be available.

3.   The use of the seasonal connection data of Navopache

Cooperative as a proxy for second-home growth is not without basis.

Hogan's survey work determined that 94 percent of the second homes

in northern Arizona had electrical service. Similarly, a 1967

study by the U.S. Bureau of the Census showed that 91 percent of

all second homes in the United States at that time had electrical

service.

THE DATA

The growth of second homes over time in the study area has

been fairly constant; however, a strong seasonal influence is

clearly evident. Figures III and IV graphically present the

seasonal hookups for Navajo County and Apache County, respectively.

Two curves are fitted on each of the figures, the unadjusted

number of seasonal electric hookups and a seasonally adjusted

number of electric hookups. The seasonally adjusted electric

hookups were computed by eliminating the trend from the time

series by a weighted moving average. Total seasonal electric

hookups in the study area increased from 636 in January of 1959

FIGURE III

NAVAJO COUNTY
SEASONAL ELECTRICAL
HOOKUPS
1959-1977
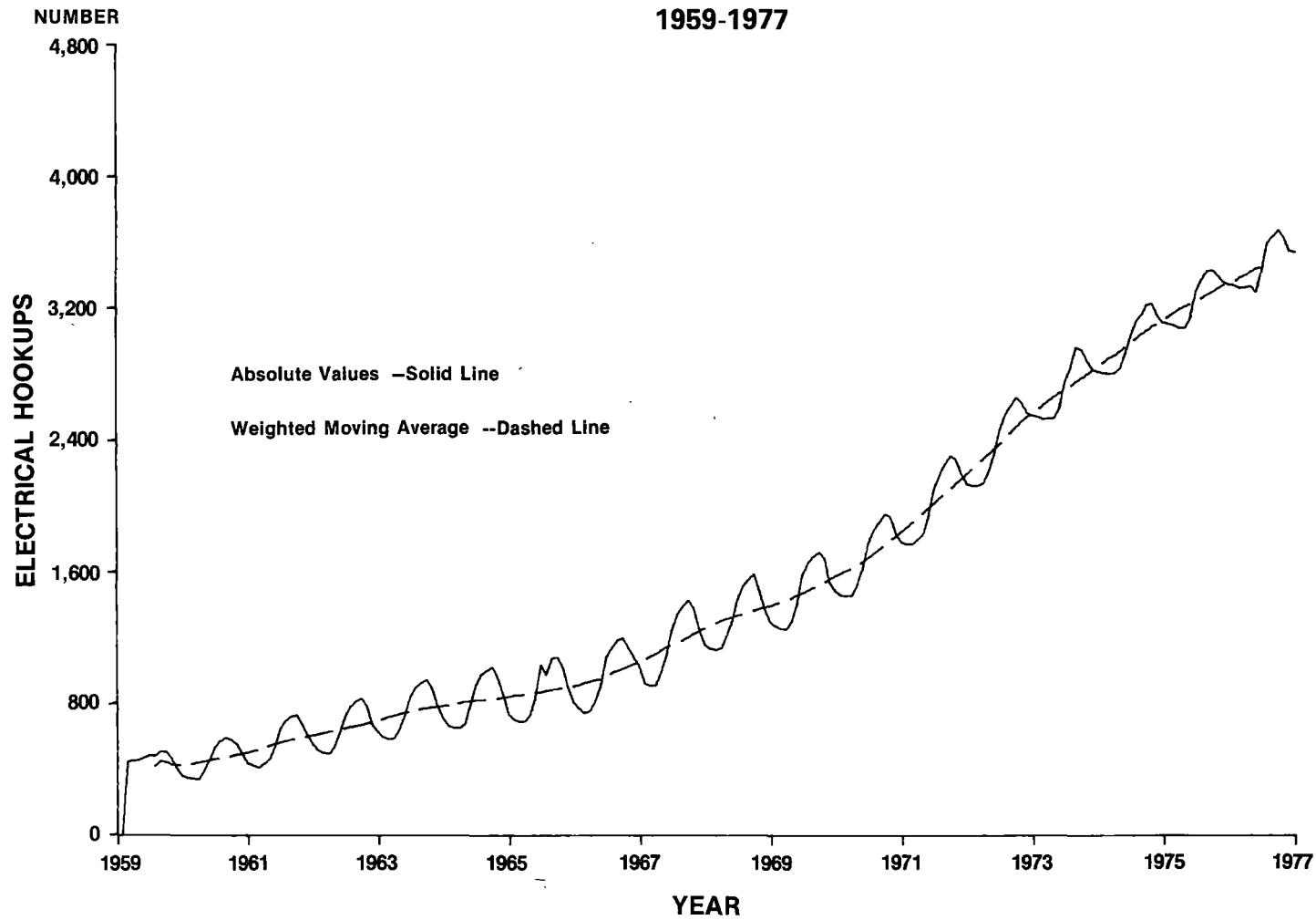
Absolute Values —Solid Line

Weighted Moving Average --Dashed Line

ELECTRICAL HOOKUPS

NUMBER

YEAR

23

FIGURE IV
APACHE COUNTY
SEASONAL ELECTRICAL
HOOKUPS
1959 - 1977
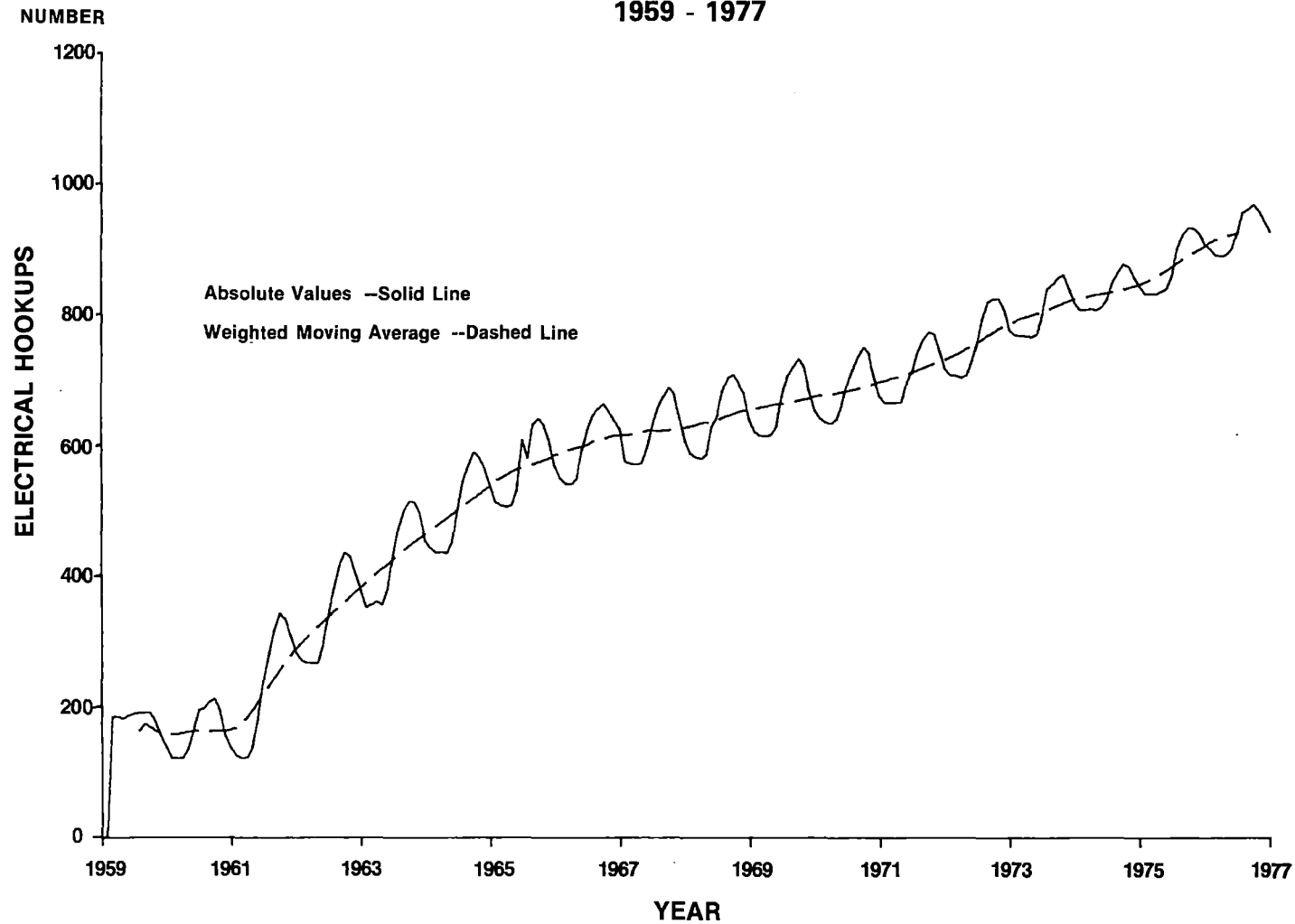
NUMBER

ELECTRICAL HOOKUPS

Absolute Values --Solid Line

Weighted Moving Average --Dashed Line

YEAR

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

to 4,474 in December of 1976. The actual and seasonally adjusted

values for electric hookups are presented in Tables 2 through 7.

OVERVIEW

One of the most difficult problems of the project was to

develop a time series of data on second-home development in the

study area that could be used with known time series data on

streamflows. Although time and funding precluded empirical

gathering of the information, the data of Navopache Electric

Cooperative provided one way to develop these estimates.

The findings of the relationships are discussed in Chapter V

while the implications and recommendations are discussed in

Chapter VI.

TABLE 2

APACHE COUNTY
UNADJUSTED ELECTRIC HOOKUPS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	--	185	185	182	187	190	192	191	191	177	155	137
1960	122	121	122	135	163	195	198	208	212	194	154	136
1961	125	121	123	139	181	239	278	317	343	335	309	282
1962	271	267	266	267	297	341	380	415	436	431	404	378
1963	352	356	361	356	381	428	473	501	515	513	494	453
1964	443	436	437	435	453	505	547	571	590	582	565	537
1965	513	508	506	509	534	609	580	634	641	631	603	566
1966	549	541	541	549	594	626	647	657	664	652	638	624
1967	575	572	571	573	597	632	659	675	689	679	642	606
1968	587	582	580	586	630	646	685	705	709	694	679	638
1969	620	615	614	616	630	677	707	721	733	720	683	653
1970	641	635	633	639	661	695	717	736	751	742	701	674
1971	665	665	666	666	699	718	746	764	774	771	744	716
1972	708	707	704	708	731	758	795	821	826	825	810	777
1973	770	769	768	767	771	800	842	848	859	862	840	819
1974	809	809	810	808	812	826	851	867	879	876	859	844
1975	834	833	833	837	842	863	903	926	935	934	926	910
1976	903	893	891	893	902	928	958	963	970	961	945	929

Source: Navopache Rural Electric Cooperative.

TABLE 3

APACHE COUNTY
ADJUSTED ELECTRIC HOOKUPS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	--	--	--	--	--	--	164	174	169	164	160	158
1960	158	159	160	162.	163	163	163	164	164	164	164	165
1961	169	176	185	196.	208	220	233	245	257	269	280	289
1962	298	306	314	322.	330	338	346	353	360	368	376	383
1963	390	398	405	411.	418	426	432	439	446	452	459	465
1964	471	478	483	490.	495	501	508	514	520	526	532	539
1965	548	550	556	560.	564	567	569	572	575	578	581	586
1966	588	593	595	597.	599	602	607	609	612	614	616	616
1967	617	618	619	621.	624	624	622	623	624	625	626	629
1968	630	632	635	636.	638	641	643	646	649	652	654	654
1969	657	659	660	662.	664	664	666	667	669	671	673	675
1970	677	678	679	680	682	684	685	687	690	693	695	698
1971	700	702	705	707	709	713	716	720	723	726	730	733
1972	736	740	745	749	754	759	764	769	774	780	785	788
1973	792	795	798	800	804	806	810	813	816	820	823	826
1974	829	829	831	833	834	835	837	840	842	843	846	848
1975	851	856	861	865	870	876	881	887	892	897	902	907
1976	912	917	920	923	925	926	--	--	--	--	--	--

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

TABLE 4

NAVAJO COUNTY
UNADJUSTED ELECTRIC HOOKUPS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	--	452	453	458	471	485	481	507	506	472	409	360
1960	349	341	339	394	462	539	573	594	578	553	493	436
1961	424	411	432	460	538	649	695	721	730	674	609	548
1962	514	496	495	537	629	725	783	815	832	785	668	627
1963	594	582	590	647	736	847	899	927	944	891	784	711
1964	664	652	652	674	798	918	978	1000	1021	956	853	734
1965	706	691	691	736	849	1038	977	1076	1082	1025	895	807
1966	774	745	759	819	918	1088	1142	1187	1198	1139	1081	1023
1967	923	911	912	991	1095	1249	1341	1391	1428	1384	1254	1156
1968	1135	1126	1136	1213	1298	1436	1513	1553	1585	1489	1371	1294
1969	1272	1253	1250	1301	1406	1585	1661	1697	1718	1682	1536	1482
1970	1458	1454	1455	1522	1624	1784	1857	1903	1950	1935	1831	1778
1971	1767	1768	1796	1826	1933	2101	2188	2256	2306	2285	2195	2134
1972	2123	2124	2143	2218	2321	2467	2558	2612	2661	2630	2567	2550
1973	2544	2530	2535	2538	2601	2759	2844	2964	2950	2885	2831	2818
1974	2811	2809	2810	2837	2929	3037	3123	3165	3227	3232	3155	3118
1975	3111	3101	3085	3083	3145	3309	3377	3431	3433	3402	3363	3346
1976	3341	3326	3328	3338	3300	3434	3601	3637	3677	3634	3548	3545

Source: Navopache Rural Electric Cooperative.

TABLE 5

NAVAJO COUNTY
ADJUSTED ELECTRIC HOOKUPS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	--	--	--	--	--	--	421	450	441	431	426	425
1960	430	438	445	451	458	465	471	477	483	491	496	503
1961	512	522	532	545	555	565	574	582	589	594	600	608
1962	614	622	630	638	647	652	659	665	673	681	690	699
1963	709	718	728	737	746	756	763	768	774	779	782	787
1964	793	799	805	812	817	823	825	828	832	835	840	844
1965	854	854	861	866	871	875	881	887	891	897	904	910
1966	914	927	937	946	956	971	989	1002	1016	1028	1043	1057
1967	1071	1087	1104	1124	1144	1158	1170	1187	1205	1224	1242	1259
1968	1275	1289	1303	1316	1324	1334	1346	1357	1368	1377	1385	1394
1969	1406	1418	1430	1441	1457	1471	1487	1502	1519	1536	1555	1573
1970	1589	1606	1623	1642	1663	1688	1713	1738	1764	1793	1818	1844
1971	1870	1898	1927	1957	1986	2017	2046	2076	2106	2134	2167	2199
1972	2230	2261	2290	2320	2349	2380	2414	2450	2483	2516	2543	2566
1973	2590	2614	2644	2668	2689	2711	2733	2755	2779	2802	2827	2854
1974	2877	2900	2917	2940	2969	2996	3021	3046	3070	3093	3114	3132
1975	3154	3176	3198	3215	3229	3246	3265	3285	3303	3324	3345	3358
1976	3368	3387	3404	3424	3444	3459	--	--	--	--	--	--

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

TABLE 6

NAVOPACHE
UNADJUSTED ELECTRIC HOOKUPS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	636	637	638	641	658	675	673	698	697	649	564	497
1960	473	464	466	529	625	744	765	800	790	751	661	579
1961	555	539	556	604	721	888	963	1038	1075	1009	892	830
1962	785	759	759	800	925	1066	1158	1226	1268	1216	1075	1000
1963	946	939	946	1003	1118	1277	1373	1431	1459	1413	1287	1171
1964	1113	1091	1097	1109	1252	1423	1524	1571	1611	1538	1418	1271
1965	1219	1199	1199	1245	1383	1571	1647	1710	1723	1656	1503	1373
1966	1323	1286	1300	1368	1512	1714	1789	1844	1862	1791	1647	1536
1967	1498	1483	1483	1564	1692	2000	2066	2066	2117	2063	1896	1762
1968	1722	1708	1716	1799	1961	2082	2196	2255	2291	2178	2047	1929
1969	1889	1865	1861	1914	2033	2259	2365	2414	2447	2398	2215	2131
1970	2095	2085	2084	2157	2281	2475	2574	2656	2701	2677	2532	2452
1971	2432	2437	2429	2492	2632	2819	2934	3020	3080	3056	2939	2850
1972	2831	2831	2847	2926	3052	3225	3353	3433	3457	3455	3377	3327
1973	3314	3299	3303	3305	3372	2559	3656	3812	3809	3747	3671	3637
1974	3620	3618	3620	3645	3741	3863	3974	4032	4106	4108	4014	3962
1975	3945	3934	3918	3920	3987	4172	4280	4357	4368	4336	4289	4256
1976	4244	4219	4219	4231	4302	4462	4559	4600	4647	4595	4483	4474

Source: Navopache Rural Electric Cooperative.

TABLE 7

NAVOPACHE
ADJUSTED ELECTRIC HOOKUPS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	--	--	--	--	--	--	639	625	611	596	587	584
1960	590	598	606	614	622	630	637	644	650	658	664	672
1961	684	701	720	744	766	785	806	825	843	860	877	894
1962	908	925	940	956	974	989	1003	1016	1031	1047	1064	1080
1963	1098	1116	1133	1149	1165	1183	1197	1211	1223	1236	1245	1256
1964	1268	1281	1292	1305	1316	1326	1335	1344	1353	1361	1372	1383
1965	1396	1406	1418	1427	1437	1444	1452	1461	1468	1477	1487	1498
1966	1510	1521	1533	1544	1555	1567	1581	1596	1612	1627	1644	1659
1967	1682	1705	1724	1745	1768	1789	1807	1826	1845	1864	1884	1906
1968	1913	1924	1940	1954	1964	1976	1990	2004	2017	2029	2039	2045
1969	2060	2074	2087	2100	2118	2132	2149	2166	2185	2203	2224	2244
1970	2262	2280	2300	2321	2344	2371	2397	2425	2455	2484	2511	2541
1971	2569	2599	2630	2661	2693	2727	2760	2793	2826	2861	2897	2932
1972	2966	3001	3035	3067	3100	3136	3176	3216	3255	3293	3325	3352
1973	3379	3405	3436	3466	3490	3514	3540	3566	3592	3619	3647	3678
1974	3703	3730	3748	3773	3803	3831	3859	3886	3912	3937	3960	3980
1975	4006	4031	4059	4080	4099	4122	4147	4172	4195	4221	4246	4273
1976	4297	4320	4340	4364	4385	4401	--	--	--	--	--	--

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

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NOTES

[1]M. E. Bond and R. H. Dunikoski, The Impact of Second-Home Development on Water Availability in North Central Arizona, Eisenhower Consortium Institutional Series Report No. 1, Bureau of Business and Economic Research, College of Business Administration, Arizona State University, 1977.

[2]T. D. Hogan, Second-Home Ownership in Northern Arizona: A Profile and Implication for the Future, Eisenhower Consortium Institutional Series, Report No. 2, Bureau of Business and Economic Research, College of Business Administration, Arizona State University, 1977.

[3]S. D. Gerking, C. J. Holmes, and M. VanBrackle, "A Short-Term Forecasting Model for Second Homes in Northeastern Arizona," Final Report in Grant 16-699-GR, U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado, 1979.

CHAPTER IV

STREAM DISCHARGE ANALYSIS

The methodology employed in this analysis relies upon secondary

data for measures of stream discharge in the study area. The

United States Geological Survey annually publishes water data

reports for Arizona in which stream discharge data are reported

from each of its gauging stations on streams throughout the state.

Using the study area defined by the Navopache Electric Cooperative

service area, the watersheds to be analyzed were identified by

hydrologic maps of northern Arizona. Those streams included all or

parts of the watersheds of Carrizo Creek, the White River, the

Black River, the Little Colorado River, and their tributaries. A

set of potentially useful gauging strations was identified on

these streams, and by field inspection, the study team selected a

subset of six gauging stations to be utilized in the empirical

investigation. A list of these stations is provided in Table 8.

Analyses of the impact of urban developement upon stream

discharge have generally demonstrated that such development affects

both the volume and time pattern of streamflow. To evaluate these

two potential types of change, monthly stream discharge data

measuring both maximum flow (in cubic feet per second) and total

discharge (in acre feet) from each of the six stations were compiled

from the annual issues of <u>Water Resources Data for Arizona</u>.[1]

TABLE 8

STREAM DISCHARGE GAUGES

| Gauge Number	Gauge Name	Gauge Location	Drainage Area (mi^2)	Period of Record
3834	Little Colorado River at Greer, Arizona	0.1 mi. downstream from filler ditch	30.9	8/60 to present
3835	Nutrioso Creek above Nelson Reservoir near Springerville, Arizona	2.4 mi. upstream from Nelson Reservoir Dam, 9 mi. SE of Springerville	83.4	6/67 to present
3905	Show Low Creek near Lakeside, Arizona	2.2 mi. upstream from Jacques Dam, 1.9 mi. NW of Lakeside, Arizona	68.6	1/59 to present
4890.7	North Fork of East Fork Black River near Alpine, Arizona	1.4 mi. downstream from Crosby Crossing, 12 mi. NW of Alpine	38.1	6/65 to present
4910	North Fork White River near McNary, Arizona	1.9 mi. downstream from Paradise Creek, 7 mi. SE of McNary	66	1/59 to present
4960	Corduroy Creek near mouth, near Show Low, Arizona	4 mi. upstream from mouth 20 mi. SW of Show Low, Arizona	203	9/51 to 9/75

Source: Compiled from U.S. Department of Interior, U.S. Geological Survey, Water Resources Data for Arizona, 1965-1976, Surface Water Records of Arizona, 1961-1964, and Surface Water Supply of the United States: Part 9, Colorado River Basin, 1959 and 1960.

Maximum flow was chosen for the investigation of shifts in the pattern of streamflow. The effects of watershed changes connected with development, such as building of roads and structures and clearing of trees and other vegetation, have almost universally been associated with a change in the pattern of runoff characterized by both a shorter flow period and a larger peak flow during that shorter time span. The maximum flow measure is employed in this study to investigate whether such a pattern of an increase in the peak flow has been associated with second-home development in the Navopache Cooperative's service area. Changes in the total volume of stream discharge will be analyzed on the basis of the total monthly flow measure.

## PATTERNS OF STREAM DISCHARGE IN THE STUDY AREA

The patterns of discharge in the streams used in the empirical analysis vary greatly in the magnitude of flow during the study period with an annual peak usually occurring in the spring, and low or zero flow during the fall. Differences in climate conditions from year to year, varying periods of summer rains, and several other factors contribute to irregular flow patterns during many of the years in the study period. The acutal flow patterns as measured by monthly total stream discharges (in acre feet) for each of the six gauging stations are presented in Figures V through X. As described in Table 8, periods of zero flow at the beginning

FIGURE V
MONTHLY TOTAL STREAM DISCHARGE
FOR GAUGING STATION 3834
1959-1976
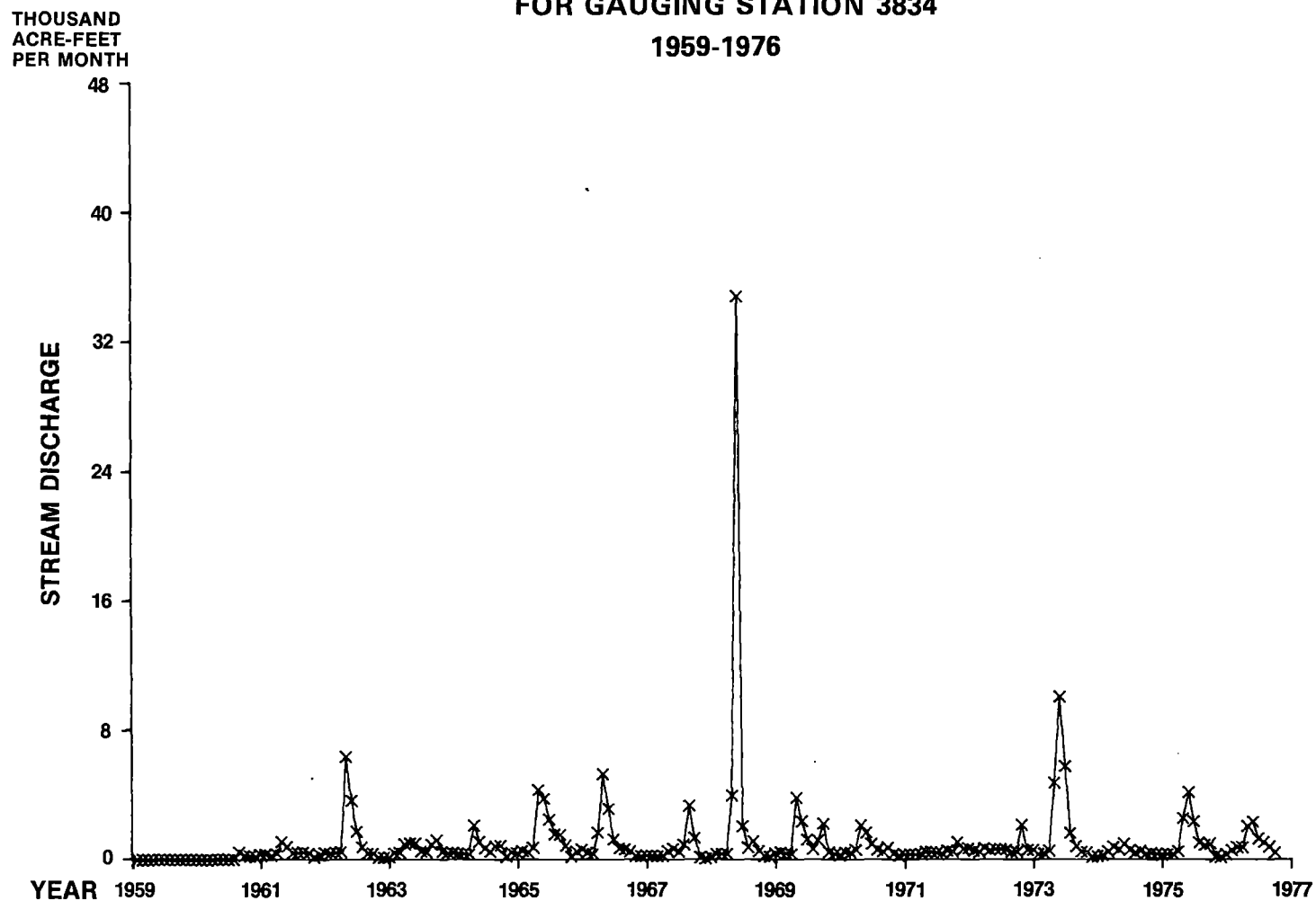
THOUSAND
ACRE-FEET
PER MONTH

STREAM DISCHARGE

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

FIGURE VI
MONTHLY TOTAL STREAM DISCHARGE
FOR GAUGING STATION 3835
1959-1976
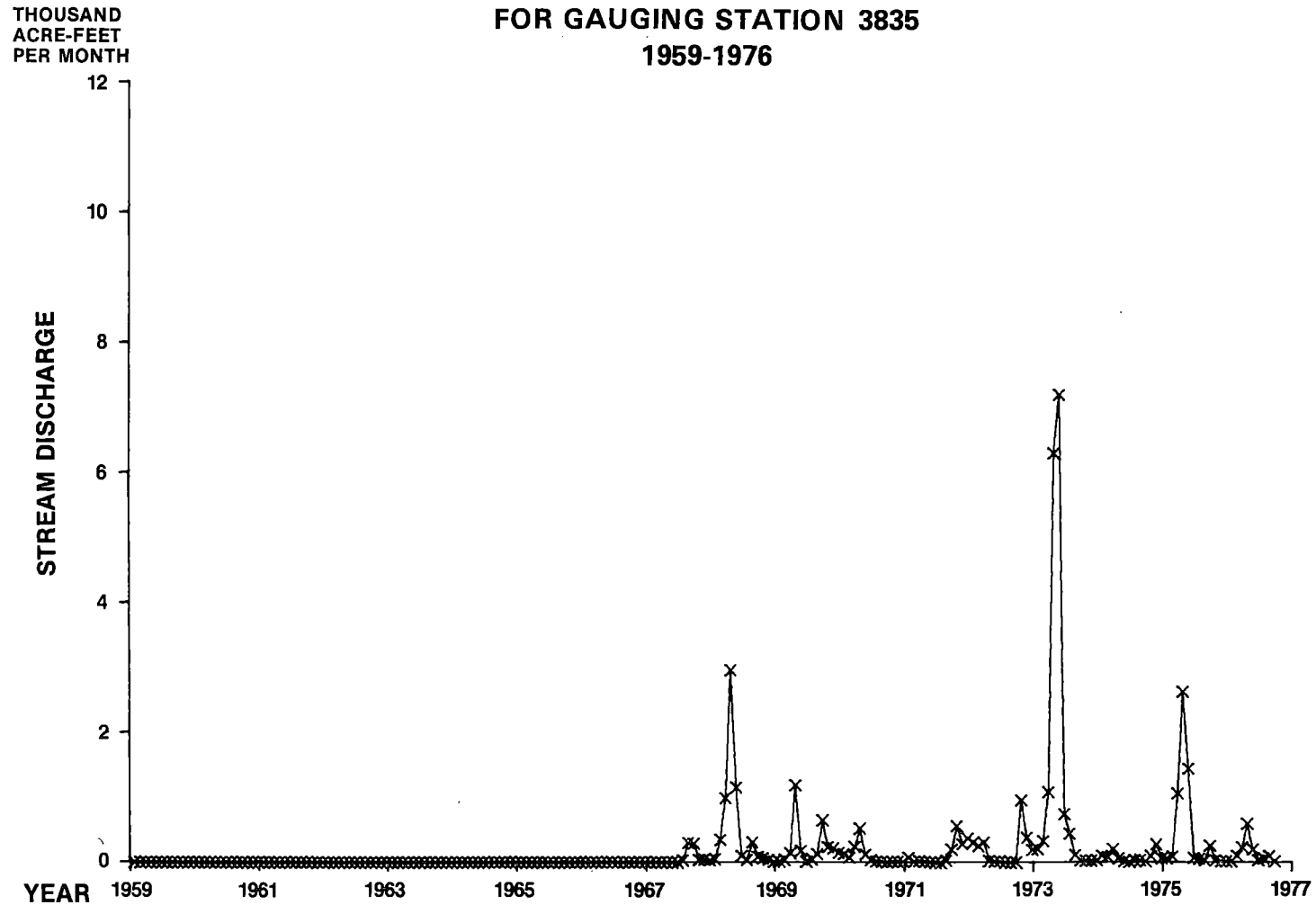
THOUSAND
ACRE-FEET
PER MONTH

STREAM DISCHARGE

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

FIGURE VII

MONTHLY TOTAL STREAM DISCHARGE FOR GAUGING STATION 3905

1959-1976
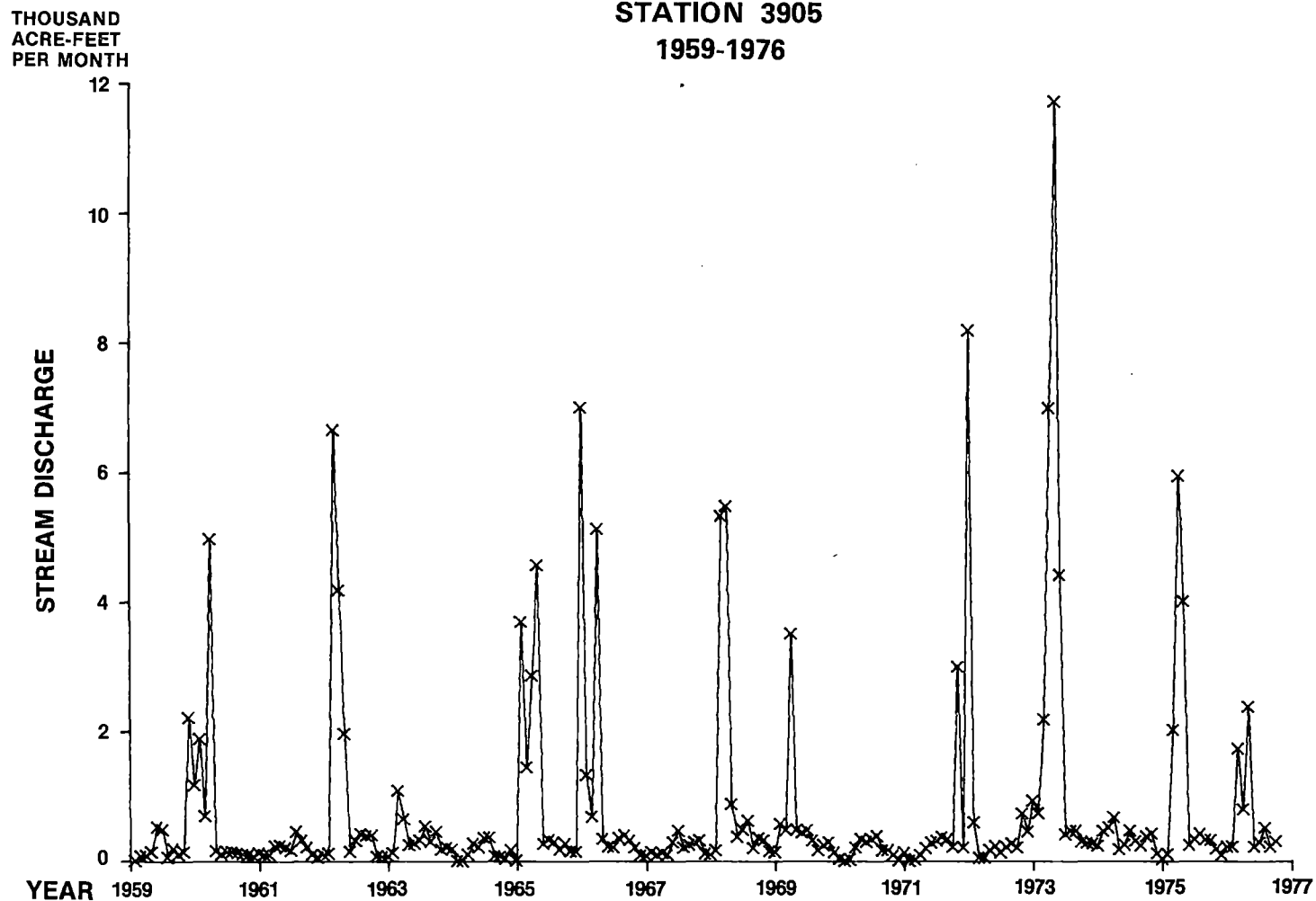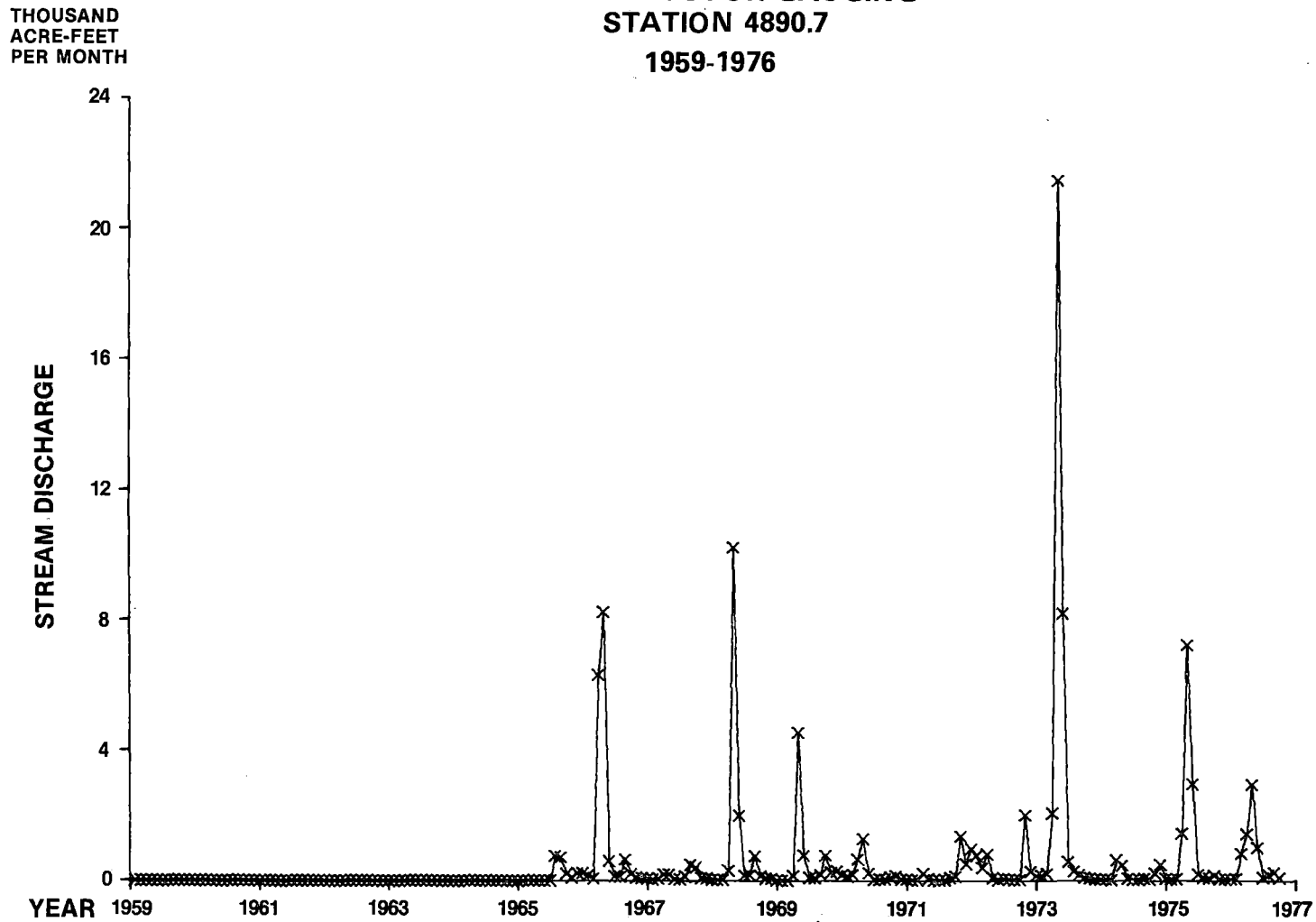
THOUSAND
ACRE-FEET
PER MONTH

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

FIGURE VIII
MONTHLY TOTAL STREAM
DISCHARGE FOR GAUGING
STATION 4890.7
1959-1976

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

FIGURE IX
MONTHLY TOTAL STREAM
DISCHARGE FOR GAUGING
STATION 4910
1959-1976
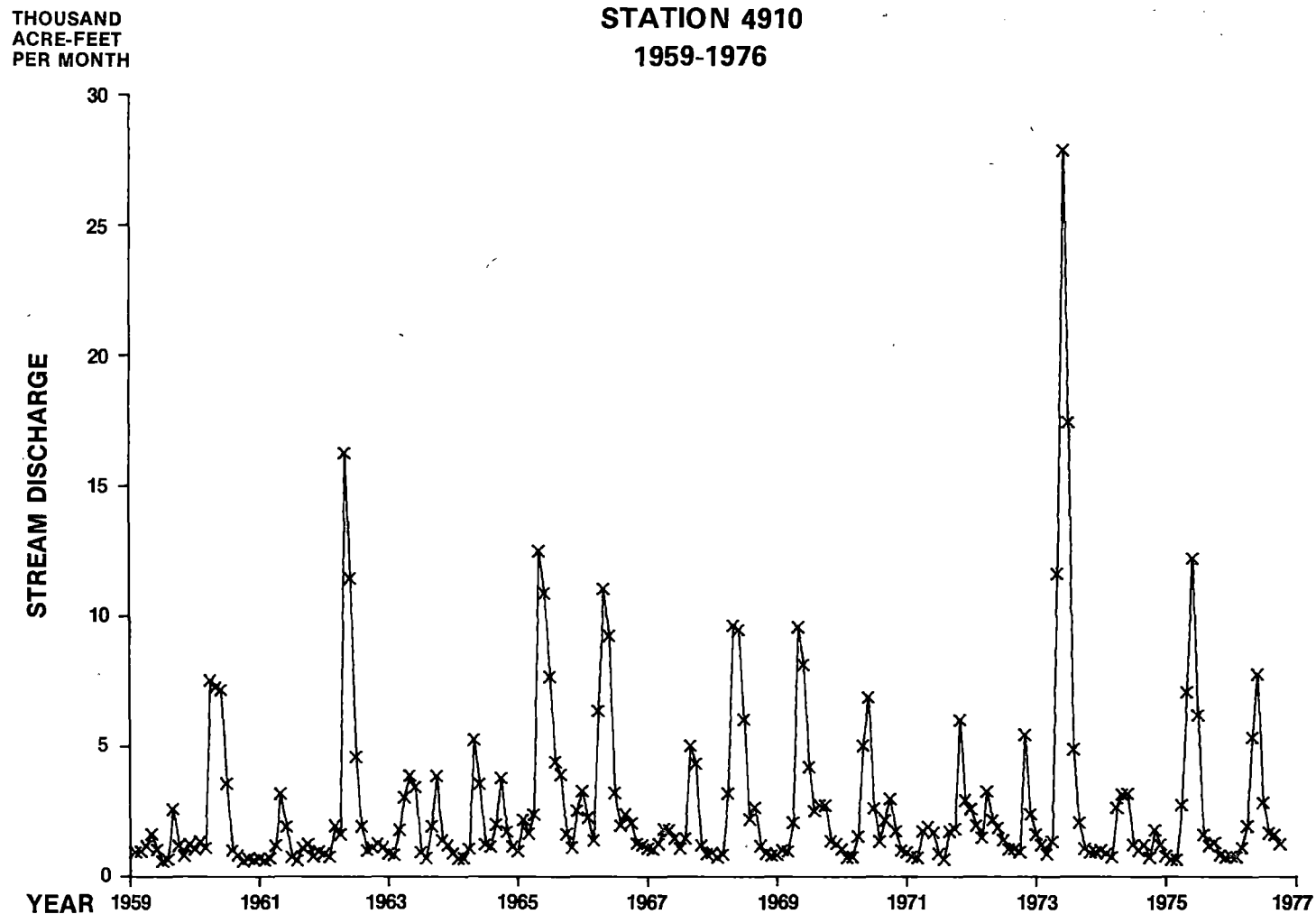
THOUSAND
ACRE-FEET
PER MONTH

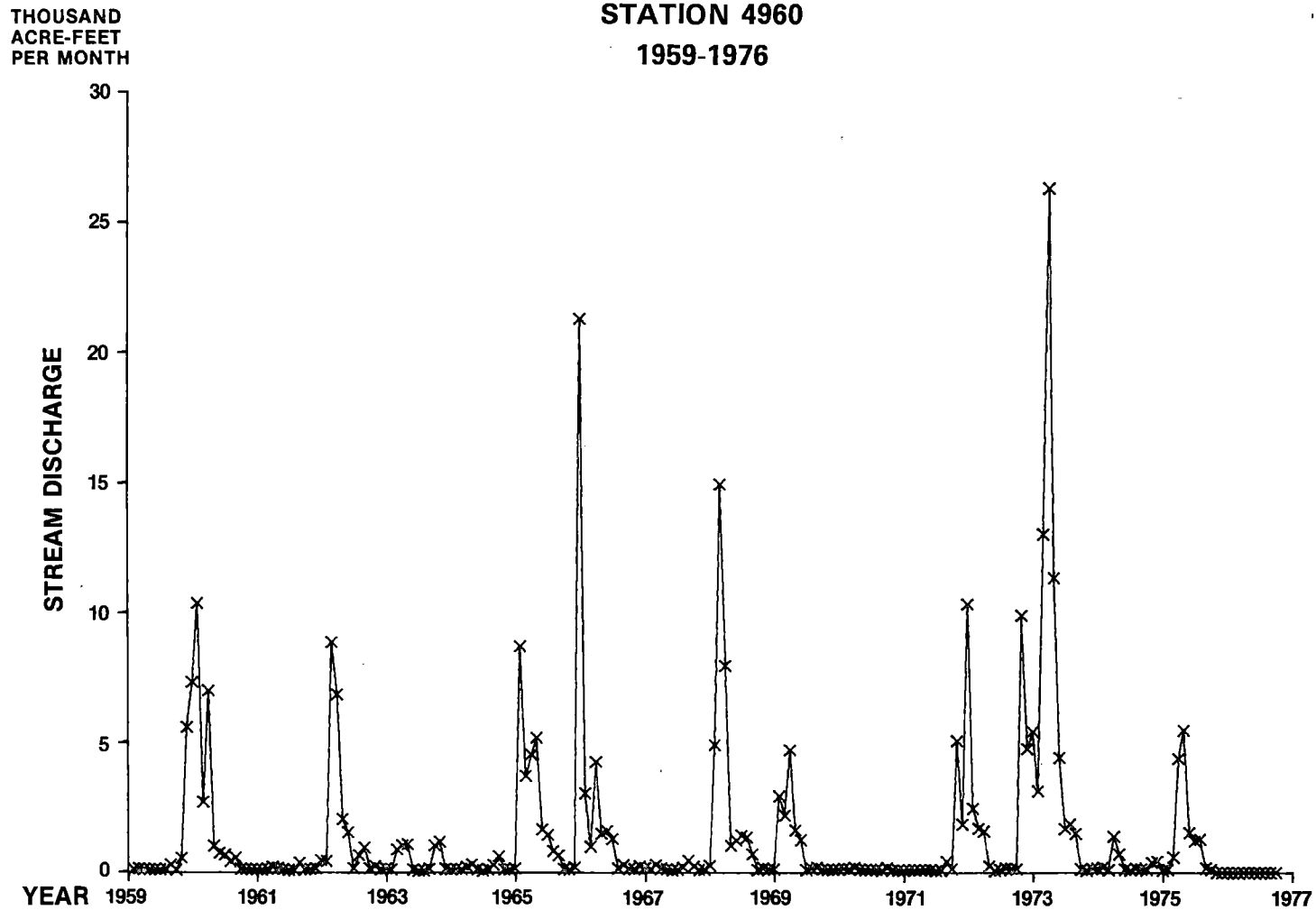Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

FIGURE X
MONTHLY TOTAL STREAM
DISCHARGE FOR GAUGING
STATION 4960
1959-1976

THOUSAND
ACRE-FEET
PER MONTH

STREAM DISCHARGE

YEAR 1959   1961   1963   1965   1967   1969   1971   1973   1975   1977

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

of the figures for stations result from a lack of streamflow data
for these gauging stations during part of the study period.

The maximum discharge series are even more erratic in nature.
While the data from some of the stations generally exhibit annual
cycles during most of the years of the study period, other gauging
stations had two or more periods of high flow during a single year,
and the magnitude of the peak flow cycles also varied tremendously
for all stations from year to year during the study period.

To provide general summary statistics of the variation in
streamflow, Table 9 lists the mean, standard deviation, minimum,
and maximum values for both the maximum flow and total monthly flow
series for each of the six gauging stations included in the analysis.
These statistics corroborate the impression provided by the graphs
presented previously, by demonstrating wide variations in both peak
and in total monthly discharge for all six of the stations.

TRENDS IN STREAM DISCHARGE
DURING THE STUDY PERIOD

Since the primary objective of this study is a time-series
analysis of the impact of second-home development upon stream
discharge in the watersheds affected by such development, close
attention must be paid to any long-run trends in the streamflow
data. Trend analysis of the stream discharge data demonstrates no
such trends, although in the preceding chapter, examination of the

TABLE 9

SUMMARY STATISTICS FOR MAXIMUM FLOW AND TOTAL FLOW SERIES

Gauging Station	Mean	Standard Deviation	Minimum Value	Maximum Value
Maximum Flow				
3834	30.67	43.75	1.50	256.00
3835	17.57	42.36	0.00	295.00
3905	63.75	229.02	0.20	2140.00
4890.7	41.51	111.28	0.20	802.00
4910	85.97	112.32	10.00	800.00
4960	134.24	477.90	1.60	4760.00
Total Flow				
3834	1090.35	2731.35	59.00	34802.00
3835	357.50	981.89	0.00	7200.00
3905	777.62	1592.17	6.00	11740.00
4890.7	806.69	2412.81	11.00	21540.00
4910	2698.98	3323.57	584.00	27900.00
4960	1523.11	3415.72	76.00	26350.00

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

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variables employed to measure second-home development identified a systematic pattern of growth in the number of second homes during the 1959-1976 study period.

Given the strong patterns of variation in most of the discharge series, it is very difficult to discern any visible time trends in the graphs of the discharge data presented in Figures V through X. To examine the possibility of such trends in a more rigorous fashion, the maximum flow and total flow series for each gauging station were regressed against time. The results of this simple linear regression analysis are presented in Table 10. The six columns in the table present estimated intercept, the estimated coefficient for the time variable, the estimated standard error of that coefficient, the computed t-statistics based upon that standard error, the coefficient of determination (R^2) adjusted for degrees of freedom, and the number of observations in the series for each regression.

For both the maximum flow and total flow series, the computed t-statistics for the estimated coefficients for the time variable indicate that none of the coefficients can be considered statistically significant from zero even at the 90 percent level of confidence. Thus, no systematic time trends in the stream discharge data can be identified.

TABLE 10

RESULTS FOR TIME TREND REGRESSIONS FOR MAXIMUM FLOW
AND TOTAL FLOW SERIES

Gauging Station	Intercept	Regression Coefficient	Standard Error of the Coefficient	t-Value	R^2
Maximum Flow					
3834	26.31	.0375	.0562	.677	.002
3835	13.65	.0248	.1260	.197	.000
3905	42.75	-.1963	.2555	.768	.003
4890.7	29.29	.0837	.2466	.339	.001
4910	74.94	.1031	.1253	.823	.003
4960	78.94	.4982	.6807	.732	.003
Total Flow					
3834	940.27	1.2882	3.5095	.367	.001
3835	188.58	1.0691	2.9202	.366	.001
3905	559.82	2.0355	1.7729	1.148	.006
4890.7	592.26	1.4687	5.3472	.274	.001
4910	2260.60	4.0970	3.7017	1.107	.006
4960	689.66	7.5085	4.8403	1.550	.013

Source: Bureau of Business and Economic Research, Arizona State University,
Tempe, Arizona.

OVERVIEW

Secondary data published by the U.S. Geological Survey have
been employed in this study to measure stream discharge. Given the
entire set of gauging stations in northeastern Arizona for which
the U.S. Geological Survey compiles stream discharge data, a
subset of six gauging stations was selected for use in the empirical
analysis. The watersheds of these six stations all are located
within the Navopache Electric Cooperative's service area, and their
selection was based upon field inspection of the location and the
surrounding area of each gauging station.

Data on both peak flow and total monthly flow at each of the
gauging stations have been compiled for the empirical investigation,
and the analyses of these data series presented in this chapter have
shown the magnitude of variation in both the peak flow and total
discharge in each of the streams during the study period.

Statistical investigation of streamflow variations during the
study period showed no systematic long-term trend in any of the
flow series. Lack of any consistent trends in the volume or peak
magnitudes of stream discharge does not necessarily imply that the
second-home development within the study area has not affected the
pattern of stream discharge. The processes that determine the
pattern and magnitude of streamflow are complex, and the actual
discharge pattern is produced by many factors, including changes
in the physical character of the watershed (such as those caused by

development). For this reason, as part of this study, multiple regression techniques have been utilized to estimate statistical models of stream discharge. These models have included the pattern of second-home development, together with other potentially significant factors as separate independent explanatory variables, in order to assess the impact of second-home development upon the stream discharge measures. The results of the regression analysis are presented in the following chapter.

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NOTES

[1]U.S. Department of the Interior, U.S. Geological Survey, Water Resources Data for Arizona, 1965-1976; Surface Water Records of Arizona, 1961-1964; and Surface Water Supply of the United States: Part 9, Colorado River Basin, 1959 and 1960.

CHAPTER V

EMPIRICAL ANALYSIS

The maximum monthly flow or the total monthly discharge series
for the six streams included in the study sample did not reveal any
observable trends over the 1957-1975 study period, although the
analysis in Chapter III clearly indicated that substantial second-
home and resort-town development had occurred in the southern
Apache County-Navajo County area during the same time period. As
a more formal test of the impact upon the pattern of stream
discharge of second-home development within the study area, multiple
regression analysis has been employed to estimate statistical
models of streamflow, with the number of second homes as one of the
individual explanatory variables included in the statistical model.

REGRESSION METHODOLOGY

In addition to second-home development as one of the explana-
tory variables in the statistical models, two measures of climatic
conditions have also been included as relevant explanatory
variables. Since the volume of flow would likely be positively
related to the volume of precipitation occurring on the watershed,
a measure of total monthly precipitation was therefore incorporated
as one of the variables in the estimating equation. It also seems
likely that the pattern of stream discharge would be related to
temperature within the watershed area; thus average monthly

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temperature was also included as the second climatic variable in the explanatory models. The connection between temperature levels and streamflow might not be a single monotonic relationship in a mountain environment. During the winter months, a positive relationship might exist between temperature and streamflow due to the effects of higher temperatures in the melting rate of the snowpack, while in summer months, a negative relationship might be expected given a positive relation between temperature and the rate of evaporation.

Other factors that might be expected to influence the pattern of stream discharge, such as soil types, topography of the area (including degree of slope), and the nature of the vegetation, would generally not be expected to change in a given location over the relatively short span of the study period without outside action such as land development, cultivation, foresting, fire damage, etc. For the purposes of this exploratory analysis, the assumption has been made that during the study period, no changes in these factors occurred that were not associated with the process of second-home development.

On this basis, statistical models of streamflow of the following general form have been estimated for the streamflow series from each of the six gauging stations included in the study sample:

$$F_{it} = a_i + b_{2i} + T_{it} + b_{3i}S_{it} + u_i$$

for i = 1, 2, 3, 4, 5, 6 -- corresponding to each of the six
gauging station locations and where

F_i = either maximum monthly streamflow or total

monthly streamflow at location "i" in month

"t",

a_i = the estimated intercept of the estimated

equation for location "i" incorporating the

net impact upon streamflow of all the

factors not explicitly included in the

equation,

b_{1i}, b_{2i}, b_{3i} = the estimated regression

coefficients for the three explanatory

variables,

T_t = average monthly temperature at location

"i" in month "t",

P_t = total monthly precipitation at location

"i" in month "t",

S_t = number of seasonal electric hookups (as a

proxy for the number of second homes) in

the county in which location "i" is situated

in month "t",

u_i = the stochastic error term for equation "i".

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CLIMATOLOGICAL DATA SOURCES

The data series employed as measures for the two climatic
variables were compiled from U.S. Department of Commerce sources.[1]
Series relating to average monthly temperatures and total monthly
precipitation were available for six locations, in or near the
study area, where various agencies maintain weather recording
stations. The exact location and the identity of the observer for
each data station are presented in Table 11. In practice,
climatological data from only two of the six stations were actively
employed in the regression equations -- data relating to the McNary
station in equations for gauging stations 3905, 4910, and 4960 and
data for Alpine for gauging stations 3834, 3835, and 4890.7.

The summary statistics shown in Table 12 demonstrate the
extent of variation in both the temperature and the precipitation
measures for both the McNary and Alpine locations. With mean
average monthly temperatures in the mid-40s, the range of average
temperatures at both stations was 42 to 43 degrees over the year
during the study period with a maximum range of 124 degrees at
Alpine (-30 to +94) and 117 degrees at McNary (-19 to +98). The
total monthly precipitation figures also varied substantially
during the study period. The levels at both stations ranged from
no precipitation to over ten inches in a particular month during
the study period with means of about two inches of precipitation
per month.

TABLE 11

CLIMATOLOGICAL DATA STATIONS

| Station Name | Location | | Elevation | Observer |
	Latitude	Longitude		
Alpine	3351	10908	8050	U.S. Forest Service
Cibecue	3403	11029	4955	Richard J. Pagels
McNary	3404	10951	7320	Southwest Lumber Mills, Inc.
Show Low City	3415	11002	6400	City of Show Low
Springerville	3408	10917	7060	U.S. Forest Service
Whiteriver	3350	10958	5280	Bureau of Indian Affairs

Source: Compiled from U.S.Department of Commerce, National Oceanic and Atmospheric Administration, Climatological Data, Arizona, Volumes 63-80.

TABLE 12

SUMMARY STATISTICS FOR AVERAGE MONTHLY TEMPERATURE
AND TOTAL MONTHLY PRECIPITATION SERIES

Location	Mean	Standard Deviation	Minimum Value	Maximum Value
Average Monthly Temperature (Degrees Fahrenheit)				
McNary	47.04	12.64	24.80	68.00
Alpine	44.61	11.63	22.30	64.10
Total Monthly Precipitation (Inches)				
McNary	2.21	1.98	--	10.73
Alpine	1.68	1.68	--	10.08

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

Given the objective of examining the impact of second-home development upon the pattern of stream discharge, the existence of systematic time trends in the two climatic measures was investigated by regressing each of the climatic series against time. The results of this simple bivariate regression analysis are set forth in Table 13. For both the average temperature and the total precipitation series, the computed t-statistics for the estimated coefficients of time variable indicate that none of the coefficients can be identified as statistically different from zero at a 90 percent level of confidence. That is, the climatological data series demonstrate no systematic time trends during the study period.

INITIAL EMPIRICAL RESULTS

Statistical models of the general form described above for monthly maximum flows and total monthly flows for each of the six gauging stations were estimated with ordinary least squares regression procedures. Results for the maximum flow equations are presented in Table 14 and for the total flow equations in Table 15. Each flow in these tables sets forth the following estimated parameters for each regression equation: the intercept term; the estimated coefficients for each of the three explanatory variables, with the corresponding t-statistic indicating the statistical significance in parentheses below each estimated coefficient; and the coefficient of determination (R^2).

TABLE 13

RESULTS OF TIME TREND REGRESSIONS FOR AVERAGE TEMPERATURE
AND TOTAL PRECIPITATION SERIES

Location	Intercept	Regression Coefficient	Standard Error of the Coefficient	t-Value	R^2
Average Temperature					
McNary	46.368	.0122	.0142	.858	.004
Alpine	43.905	.0066	.0133	.499	.001
Total Precipitation					
McNary	1.785	.0030	.0021	1.408	.010
Alpine	1.575	.0003	.0018	.170	--

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

TABLE 14

REGRESSION RESULTS: MAXIMUM FLOWS

| Gauging Station | Intercept | Coefficients | | | R^2 |
		Average Temp.	Total Precip.	No. of Seasonal Hookups	
3834	2.478	.666 (1.486)	2.022 (.581)	-.009 (.122)	.032
3835	26.445	- .275 (.523)	.974 (.228)	.004 (.005)	.004
3905	256.921	-5.372 (2.320)	34.123 (2.427)	.001 (--)	.135
4890.7	103.953	-1.046 (.752)	-4.000 (.352)	-.009 (.045)	.016
4910	58.580	1.025 (.807)	3.363 (.436)	-.010 (.383)	.012
4960	411.868	-8.031 (2.797)	55.572 (3.187)	-.018 (.313)	.198

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

TABLE 15

REGRESSION RESULTS: TOTAL FLOWS

		Coefficients			
Gauging Station	Intercept	Average Temp.	Total Precip.	No. of Seasonal Hookups	R^2
3834	5118.014	42.718 (1.266)	-139.545 (.749)	-7.429 (1.432)	.044
3835	579.097	- 7.169 (.540)	- 38.596 (.356)	.305 (.170)	.010
3905	2315.909	-50.969 (2.837)	293.320 (2.689)	.209 (.591)	.181
4890.7	2564.146	-21.903 (.687)	-147.132 (.536)	- .539 (.118)	.019
4910	1790.920	45.586 (1.153)	- 34.815 (.145)	- .375 (.481)	.021
4960	5576.547	-109.282 (3.211)	801.209 (3.876)	- .263 (.392)	.258

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

The first analysis looks at the coefficient of determination, which provides a measure of the overall explanatory power of each of the estimated regression equations. Specifically, it measures the proportion of total variance in the dependent variable "explained" by the set of independent variables -- that is, an R^2 value of .789 implies that 78.9 percent of the variance in the dependent variable is "explained" by the estimated equation. It can be seen that the three-variable linear equations perform very poorly as models for the pattern of variation in the stream discharge measures. The R^2 statistics show that only in the case of the total flow equation for gauging station 4960 is more than 25 percent of the total variance explained by the statistical model. In fact, most of the equations can only explain 1 to 2 percent of total variance in the streamflow variables.

Examination of the t-statistics associated with the individual regression coefficients generally indicate that the estimated coefficients are not statistically different from zero. That is, the formal statistical analysis does not show the independent variables to have had significant impacts upon the pattern of variation in the stream discharge series. Only in the case of streamflow at stations 3905 and 4960 did the t-statistics for the estimated coefficients for the temperature and the precipitation measures imply that these variables had significant influences upon the pattern of variation in stream discharge. The regression

findings indicated significant negative relationships between average temperature and both maximum and total flow. Similarly, a positive and statistically significant relationship was found between total precipitation and total stream discharge. In no case was any association shown between second-home development and the pattern of stream discharge within the study area.

REGRESSION RESULTS WITH SEASONALLY ADJUSTED DATA

Previous examination of both the stream discharge and second-home data identified strong seasonal patterns in both time series. Furthermore, the character of the seasonal patterns in the second-home data and water data were not closely linked. As presented in Chapters III and IV, the seasonal hookup (second-home) series have predictable annual cycles with a peak each summer and a nadir during the winter period, while the water series were found to have much more complex patterns of variation. For both types of data, a high proportion of total variance in the series was due to seasonal and other short-term factors.

Given the purpose of this study, such fluctuations are not of primary interest to the analysis; rather the objective is to examine the impact of the growth trend in second-home development upon the pattern of stream discharge within the study area. Therefore, all of the data series were seasonally adjusted through use of the twelve-month moving average procedure previously referred to

in Chapter III, and another set of regression equations was estimated employing these seasonally adjusted data. The results of these regressions are set forth in Table 16 for the maximum flow series and in Table 17 for the total flow series.

After seasonal adjustment of the data, the results are substantially different than the initial regression findings. The estimated equations computed with seasonally adjusted series were able to explain a much higher proportion of the total variance of the streamflow series; of course, the total variance in these data was much smaller in magnitude than the variance figures in the original series -- for example, the total variance of the nonadjusted maximum flow series for gauging station 3834 was 1914.306 and after seasonal adjustment was 307.440. The computed R^2 statistics imply that the statistical models are able to explain 37 to 67 percent of the total variance in the streamflow series compared with the 0 to 25 percent experience with the initial equations.

Turning first to the findings with respect to the seasonal hookup variable -- the measure employed in this investigation to assess the impact of second-home development -- the results for the maximum flow equations demonstrate a statistically significant and positive relationship for only two of the six gauging stations included in the study sample. The t-statistics for the coefficients of the second-home variable did not indicate any significant impact of the number of second homes upon peak streamflow in the other four maximum flow equations.

TABLE 16

REGRESSION RESULTS: SEASONALLY ADJUSTED MAXIMUM FLOWS

		Coefficients			
Gauging Station	Intercept	Average Temp.	Total Precip.	No. of Seasonal Hookups	R^2
3834	456.974	-10.003 (3.994)	7.782 (1.868)	.035 (1.525)	.435
3835	- 5.555	- 1.475 (4.939)	7.693 (1.753)	.094 (4.423)	.466
3905	-2132.048	41.732 (3.993)	112.694 (6.495)	- .007 (.589)	.376
4890.7	- 27.875	- 3.499 (5.588)	17.618 (1.914)	.241 (5.439)	.534
4910	897.210	19.129 (2.962)	32.329 (3.015)	.008 (1.102)	.451
4960	-2409.364	40.529 (1.992)	288.131 (8.528)	- .005 (.232)	.593

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

TABLE 17

REGRESSION RESULTS: SEASONALLY ADJUSTED TOTAL FLOWS

		Coefficients			
Gauging Station	Intercept	Average Temp.	Total Precip.	No. of Seasonal Hookups	R^2
3834	24422.265	-434.069 (2.859)	557.490 (2.207)	-5.510 (3.957)	.441
3835	-12.671	- 37.229 (4.900)	-4.084 (.032)	2.509 (4.662)	.373
3905	7404.889	-187.829 (2.529)	761.423 (6.175)	.244 (3.066)	.670
4890.7	511.006	- 79.913 (5.220)	-8.376 (.032)	4.659 (4.300)	.383
4910	39862.962	-821.150 (4.074)	316.630 (.946)	.370 (1.714)	.379
4960	10421.174	-317.154 (1.556)	2533.161 (7.486)	.187 (.856)	.674

Source: Bureau of Business and Economic Research, Arizona State University, Tempe, Arizona.

The total flow equations provide more evidence of impacts of second-home development upon the volume of stream discharge. The estimated coefficients of the second-home variables in four of the six equations were found to be both positively and statistically significant. In the estimated equation for station 4960, only the coefficient for precipitation was indicated to be statistically different from zero at even the 90 percent level of confidence. At the same time, the R^2 statistics for that equation implied that the statistical model explained more than 67 percent of total variance in total streamflow. The potential weaknesses of the empirical analysis will be covered in the next chapter, but one possible explanation for these results might be that the characteristics of the watershed of this gauging station were such that changes in the volume of precipitation swamped the influences of the other two factors. With the other equation, for station 3834, the regression results imply a significant negative relationship between second-home development and stream discharge. This empirical finding is contrary to the expected result, and might be due to the specific nature of the watershed area for that particular gauging station. It was beyond the scope of the present investigation to become involved in detailed field work studying the characteristics of each watershed, but such a case study methodology would be very interesting in gaining a better understanding of the development-streamflow relationship in rural mountain areas.

A brief examination of findings for the climatic measures
reveals that the results for the maximum flow equations show some-
what conflicting results relating to the temperature variable. The
computed t-statistics imply a statistically significant relationship
between average monthly temperature and peak flow in all six
equations, but the signs of the regression coefficients indicate a
negative relationship in four cases and a positive one for the
other two cases. This evidence supports the contention that the
connection between temperature and streamflow is not a simple,
unchanging relationship over all temperature ranges. Additional
regressions were estimated including average temperature^2 -- in
addition to average temperature as explanatory variables -- in an
attempt to examine the nature of the relationships, but these
regressions did not provide any additional information and are not
reported. The evidence relating to the precipitation variable were
more straightforward -- a significant positive connection between
peak flow and the total monthly precipitation was found in all six
equations.

The results were somewhat different for the total flow equa-
tions (Table 17). Evidence of a significant negative relationship
between temperature and total stream discharge was found in five
of the six equations. On the other hand, significant positive
connections between total streamflow and total precipitation were
indicated in just half of the regression models.

OVERVIEW

The initial regression analysis did not generally produce statistical models that were able to explain a substantial proportion of the total variance in the streamflow series. Furthermore, the intial equations provided no evidence of an observable impact of second-home development upon the pattern of stream discharge. However, after the data series were seasonally adjusted so that the empirical analysis could focus upon the relationship between the growth of the number of second homes upon the pattern of streamflow, the statistical models estimated by linear regression procedures provided some evidence of a positive connection between second-home development and the pattern of streamflow. The existence of a possible relationship between such development and the volume of stream discharge was supported by the regression results of four of six equations, while the evidence in support of a significant impact of second-home development upon the time pattern of streamflow was weaker -- a positive and significant relationship was found in only two of six maximum flow equations.

NOTES

[1]U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Climatological Data, Arizona, Volumes 63-80.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

The study results provide positive evidence that second-home developments have effects on the immediate area watershed. In particular, it appears that the volume of stream discharge is increased as second-home developments reallocate utilization of the land from one production form to another. This evidence of a positive relationship was found, however, only after the data series were seasonally adjusted. And it must be recognized that, although the initial hypotheses were confirmed, the estimated magnitude of the impacts and the statistical precision of the estimated relationships were not overly strong.

There are several recommendations that can be offered for others who may choose to pursue the topic in additional depth:

Initially, the study results were probably affected by the data series that were used. Since primary data gathering of time series was not possible, available secondary data had to be used. The Navopache data were the best available; however, these were a second best proxy of trends in second-home development. Similarly, since certain gauging stations were geographically away from second-home development, the precision of the empirical tests of the hypothesized relationships was necessarily compromised. Thus, further study should consider development of alternate measures of

both the streamflow and second-home development variables; more careful measurement should strengthen the conclusions.

Secondly, the topic is highly appropriate for forest-use planning. Second-home developments offer many noteworthy advantages to the homeowner and to the adjacent economy. These developments, however, affect the entire ecosystem in the forested area. Wildlife, grazing, lumber production, recreational use, and water yield are all affected by changes to a watershed. Accordingly, orderly planning for forest area development requires a closer understanding of these types of impacts.

Thirdly, the findings of this study also imply that individuals and/or agencies involved in watershed management should be concerned with the magnitude and the pace of second-home development. The changes that will necessarily occur within the affected watersheds will tend to increase the volume of surface flow. Additional management activities will probably be needed to take optimal advantage of this increased yield to benefit downstream users. While encouragement of second-home development within their watersheds is outside the scope of such agencies' activities, second-home development is likely to occur on a significant proportion of privately-held land in many forested areas in Arizona and other western states where water is a critical resource, so that the possible impacts of such development on the watersheds should be carefully integrated into the planning activities of those states.

Fourth, it seems that the literature on this problem has maintained what might be termed a "dual-discipline separation." That is, there are the studies on stream discharge and related topics; there also are the studies on second homes and recreational areas. But the two disciplines rarely explore the joint impacts unless the analyses are done simultaneously in the form of an "environmental impact statement" or similar study type. More work that will bridge this discipline gap could be useful to planners and policy makers.

Finally, it is recognized that these conclusions apply to a narrow period of time and a small area within Arizona. The time dimension may not be significant, but a broader base of geographical study should be considered for future research. The popularity of second-home developments, when considered in concert with the public call for better planning of the use of our forested areas, requires this broader examination in other regions with forested areas now undergoing or available for such development.